"wharrow," used to give momentum to the spindle, and maintain its rotation after the act of twisting, and casting it from the hand of the spinster. In this act the verticillum was often lost, dropped, and, not thought worth the trouble of picking up, it was often cast away as worthless.

After a long search, it was at last found that the heraldic description of the coat of arms of the family of Trefuss, in "Guillim's Display of Heraldry," p. 300, supplied the obsolete English name given above of the verticillum, and thus completed a series of titles for unmarried females, proving that the three instruments used by the spinsters of antiquity and of the middle ages had suggested English words; as if the several implements, the spindle, the distaff, and the wharrow, had been considered insignia of those denominations of women who were, or who claimed to be, unmarried, or who acted as if they were unmarried; consequently, it was inferred that the three instruments used by spinners formerly might be considered as proper insignia of unmarried women, or married women in marital rebellion, but not of married women properly so called, who, as *wives*, were considered by the analogy of language to be *weavers*, and who continued to act up to those vows of obedience to the laws of the land and morality to which they promised to conform for life when they were married.

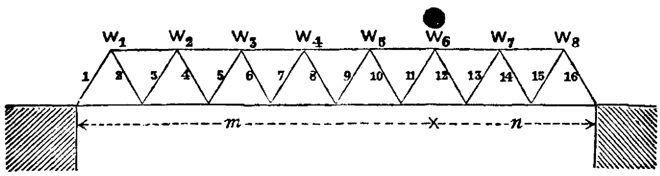
It was explained that the cases quoted in Mr. Akerman's paper, in which it was inferred that the spindle and distaff, taken together, were the insignia of wives, or weavers, as well as of *spinsters*, or spinners, when properly investigated, led to a different conclusion, and that the proper insignia of the woman considered to be a *wife* should always imply the loom or its productions, a warp or woven fabric, and not a mere thread or yarn, or any instrument used for spinning it.

BINDON B. STONEY, C. E., M. R. I. A., read a paper—

ON THE APPLICATION OF SOME NEW FORMULÆ TO THE CALCULATION OF STRAINS IN BRACED GIRDERS.

UNTIL within the last ten years our knowledge respecting the strains in the vertical portion or web of flanged girders has been very limited, and crude and imperfect views still prevail respecting the duty which this portion of a girder has to perform. Various, indeed, have been the opinions of so-called practical men on the subject. Some say the web keeps the flanges apart; others conceive that it holds them together; but comparatively few have perceived that its essential duty is to transmit the vertical pressure of the load to the abutments, producing in so doing horizontal strains in the flanges, or, if they have acknowledged this to be its proper function, they have failed to follow out their reasoning to its legitimate result, viz., that the web sustains strains which are essentially characterized by the oblique direction in which they act, and which can be practically determined both in direction and amount, enabling the engineer to dispose of the material in the most economical manner, so that its full capabilities of sustaining strain may be called into play.

In investigations respecting braced girders, it is desirable, as in other researches, to proceed from the simpler to the more complex case. I shall, therefore, first consider the strains produced by a single weight, in a girder containing but one system of triangles (Fig. 1). And I would here observe, that this paper contains merely a modification and extension of the principles of bracing already ably investigated by W. B. Blood, Esq., and R. H. Bow, Esq., who were the first to apply accurate methods of calculation to diagonally braced girders.



Suppose that the weight W_6 divides the girder into segments containing respectively m and n bays. On the principle of the lever, the pressure on the right abutment $= \frac{m}{l}$ W, that on the left $= \frac{n}{l}$W; l representing the number of bays in the whole span $(= m + n)$.

Now each of these components of the weight is transferred to the abutments through the diagonals, for vertical forces cannot pass along the horizontal flanges. Consequently, $\frac{m}{l}$ W is transmitted through each diagonal on the right of W; and this quantity is the vertical component of the strain in each of these diagonals. The actual strain is to its vertical component as the length of the diagonal is to the depth of the girder, or, calling the angle of inclination of a diagonal to a vertical line θ, we have the strain in each diagonal in the right segment—

$$\text{Strain} = \frac{m}{l} \text{W} \sec \theta. \qquad \text{(I.)}$$

In the left segment—

$$\text{Strain} = \frac{n}{l} \text{W} \sec \theta. \qquad \text{(II.)}$$

The strains in the diagonals of each segment are alternately compressive and tensile.

If the load be uniformly distributed, so that the same weight rests upon each apex, or if it be symmetrically disposed on either side of the centre, the strains in the diagonals gradually increase from the centre towards the ends. Any two diagonals equally distant from the centre sustain all the intermediate load. If they are tension diagonals, the weight is suspended, as it were, between them; if they are compression diagonals, it is supported by them as oblique props. Each diagonal conveys therefore to the abutment the pressure of the weights between it and the centre, and the sum of these weights constitutes its vertical

component. Hence, if there be n weights between any given diagonal and the centre, we have for a uniform load

$$\text{strain} = n\mathrm{W} \sec\theta, \qquad \text{(III.)}$$

W being the weight resting on each apex.

When the load is a moving load, such as a railway train, the maximum strain in any diagonal occurs when the front or end of the train is passing it. If, for instance, a train of carriages cover the right segment of the girder, diagonal 11 sustains the maximum compression which the train can produce in it; for if a weight rest upon any apex in the other segment, some portion of this weight will tend to pass to the right abutment through diagonal 11, producing in it a tensile strain, that is, a strain of an opposite kind to that produced by the train, and so will diminish the amount of the compression which existed before the additional weight was added.

On the other hand, the maximum tension in diagonal 11 occurs when the train covers the left segment, and any weight resting upon the right segment will tend to diminish this. Hence, the maximum strains in any diagonal occur when the passing load covers one or other segment into which it divides the girder; and these strains may be obtained by tabulating those produced by each weight separately, and then selecting that combination which produces maximum strains.

The annexed Table represents this method applied to the girder, Fig. 1.

The length of the girder = 80 feet, and the load = 1 ton per running foot, which is equivalent to 10 tons resting upon each apex. Let the angle $\theta = 30°$,—whence $\sec\theta = 1{\cdot}154$; and let l = the number of bays in the span, = 8.

	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	Maximum Compression.	Maximum Tension.	Uniform Load.
1	+10·8	+9·4	+7·9	+6·5	+5·1	+3·6	+2·2	+0·7	+46·2	0·0	+46·2
2	+ 0·7	−9·4	−7·9	−6·5	−5·1	−3·6	−2·2	−0·7	+ 0·7	−35·4	−34·7
3	− 0·7	+9·4	+7·9	+6·5	+5·1	+3·6	+2·2	+0·7	+35·4	− 0·7	+34·7
4	+ 0·7	+2·2	−7·9	−6·5	−5·1	−3·6	−2·2	−0·7	+ 2·9	−26·0	−23·1
5	− 0·7	−2·2	+7·9	+6·5	+5·1	+3·6	+2·2	+0·7	+26·0	− 2·9	+23·1
6	+ 0·7	+2·2	+3·6	−6·5	−5·1	−3·6	−2·2	−0·7	+ 6·5	−18·1	−11·6
7	− 0·7	−2·2	−3·6	+6·5	+5·1	+3·6	+2·2	+0·7	+18·1	− 6·5	+11·6
8	+ 0·7	+2·2	+3·6	+5·1	−5·1	−3·6	−2·2	−0 ·7	+11·6	−11·6	0·0

The letters in the upper row represent the weights at each apex, and the numbers in the first column, the diagonals in order of position.

The number found at the intersection of a diagonal with a weight represents in tons the strain produced in the diagonal by the weight in question. The sign + prefixed to a strain signifies that it is compressive; the sign − that it is tensile.

The 10th and 11th columns contain the maximum strain of both kinds, compressive and tensile, which the moving load can produce. These are obtained by adding the numbers in the several rows—first, those expressing compressive strains; and, secondly, those expressing tensile.

The last column contains the strains which the load produces when distributed uniformly all over. These are obtained by adding algebraically the strains in the several horizontal rows; or, more simply, by taking the difference of the two preceding columns.

The table, on examination, will be found to corroborate what has been already stated, viz., that the maximum strains in the diagonals occur when the passing load covers, not the whole girder, but one segment merely.

Thus, in the 6th row from the top, we find that weights 1, 2, and 3, in the left segment, produce compression in diagonal 6, while all the weights in the right segment produce tension. If, however, the load cover the whole girder, the resulting strain is equal to the *difference* between the sum of the tensile and the sum of the compressive strains, i. e. is the same as would occur if weights 4 and 5 alone rested on the beam.

The preceding method is the usual one; if, however, we wish to express the maximum strains by formulæ, we must divide Girders into two classes:—

Class A.

Girders in which the first loaded apex is distant one *whole bay* from the abutment.

Let there be n loaded apices between any given diagonal and the abutment. The strain produced by the weight at—

$$\text{The 1st apex} = \frac{W}{l} \sec\theta.$$

$$\text{2nd apex} = 2\,\frac{W}{l} \sec\theta.$$

$$\text{3rd apex} = 3\,\frac{W}{l} \sec\theta.$$

$$\cdots\cdots\cdots\cdots$$

$$n^{th}\ \text{apex} = n\,\frac{W}{l} \sec\theta.$$

The maximum strain is equal to the sum of these separate strains. Hence—

$$\text{Max. strain} = (1 + 2 + 3 + \;.\;.\;.\;.\; n)\,\frac{W}{l} \sec\theta.$$

$$\text{Max. strain} = (1 + n)\,\frac{n}{2}\,\frac{W}{l} \sec\theta. \qquad \text{(IV.)}$$

Class B.

Girders in which the first loaded apex is distant one *half-bay* from the abutment. The strain produced by the weight at—

$$\text{The 1st apex} = \frac{W}{2l} \sec\theta.$$

$$\text{2nd apex} = 3\frac{W}{2l} \sec\theta.$$

$$\text{3rd apex} = 5\frac{W}{2l} \sec\theta.$$

. . . .

$$n^{th} \text{ apex} = (2n-1)\frac{W}{2l} \sec\theta.$$

Summing up these, we have—

$$\text{Max. strain} = \{1 + 3 + 5 + \ldots (2n-1)\}\frac{W}{2l} \sec\theta.$$

$$\text{Max. strain} = \frac{n^2}{2}\,\frac{W}{l} \sec\theta. \qquad \text{(V.)}$$

Example:—The maximum tension in diagonal 11, Fig. 1, occurs when weights 1, 2, 3, 4, and 5 rest upon the girder, in which case $n = 5$, and we have—

$$\text{Max. strain} = \frac{25}{2} \times \frac{10}{8} \times 1{\cdot}154 = 18 \text{ tons.}$$

This should equal the maximum tension in diagonal 6, already tabulated, which it does.

Lattice Girders.

To proceed, next, to the lattice girder.—And first, I may remark, that latticed bracing has no theoretic advantage over a single system of triangulation; its advantages are entirely of a practical nature, consisting in the frequent support which the tension diagonals give to those in compression and which both give to the flanges.

Long pillars are serious practical difficulties, and the lattice tension bars subdivide what would otherwise be long pillars into a series of shorter ones, and hold them in the direction of the line of thrust. That this does not injuriously affect the tension diagonals will be evident when we reflect that the longitudinal strain produced in them by the deflection of a strut bears the same ratio to the strain transmitted through the strut as the deflection or versine of the curve bears to the half strut—an amount quite inappreciable in practice. If, for instance, a strut be ten feet long, and its central deflection equal one-inch (an amount much greater than ever occurs in practice), the longitudinal strain produced by this deflection in the tension bar, which intersects the centre of the strut, and restrains it from further deflection, equals $\frac{1}{60}$th of the thrust passing through the strut; so that in most cases a stout wire in tension would be sufficiently strong to hold the struts in

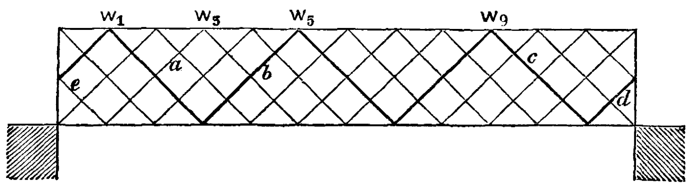
the line of thrust; and this reasoning applies to deflections both in the plane of the girder and at right angles to it.

This consideration shows that the apprehension of long compressive bars yielding by flexure—an apprehension expressed by the most eminent advocates of the plate or continuous web—need not deter us from applying diagonal bracing to girders exceeding in length any girder-bridge hitherto constructed.

It also serves to explain the otherwise anomalous strength and rigidity of lattice girders whose struts as well as ties are formed of thin bars. Such a mode of construction is, however, more or less defective. The struts should be formed of angle-iron, or the material should be thrown into some other form than that of a thin bar, which is quite unsuitable for resisting flexure at right angles to the plane of the web.

In order to calculate the strains of a lattice girder, we must consider each system of triangulation separately.

Suppose, for instance, a load distributed over the upper flange of the girder represented in *Fig.* 2—



The strains in any diagonal, b for example, are produced by the weights resting upon the apices of its own system of triangulation, W_1, W_5, and W_9, and the weights on the other apices do not affect it at all. The maximum compressive strain in diagonal b occurs when apices 5 and 9 of its system alone are loaded, and 1 is free from load, and in general, the maximum strain in any diagonal occurs when the moving load covers the greater segment of the girder, but is due merely to those weights which rest on the apices of its own system. The end pillars act as girders as well as pillars, for they transmit to the flanges the horizontal resultant of the strains in the diagonals which intersect them. This resultant is in general of small value, for it is the *difference* between the horizontal components of the strains in the intersecting diagonals. The strains in the bracing of lattice girders may be obtained by tabulating the strains produced by each weight separately, as already explained. This is, however, a tedious process, and they may be more conveniently obtained by the use of an equation obtained as follows:—

Let W = the weight liable to rest on each apex.

l = the number of bays in the span.

d = the number of bays in the depth.

n = the number of bays between the $\left\{\begin{matrix}\text{top}\\ \text{bottom}\end{matrix}\right\}$ of the given diagonal and the further abutment, when the load traverses the $\left\{\begin{matrix}\text{top}\\ \text{bottom}\end{matrix}\right\}$ flange.

p = the integer number of times that its own system occurs between the $\left\{\begin{matrix}\text{top}\\ \text{bottom}\end{matrix}\right\}$ of the given diagonal and the further abutment, when the load traverses the $\left\{\begin{matrix}\text{top}\\ \text{bottom}\end{matrix}\right\}$ flange, = the integral part of $\frac{n}{2d}$.

Let there be n bays between the diagonal b and the right abutment; then, on the principle of the lever, the portion of W_5 which is transmitted to the left abutment through b equals $\frac{n}{l}W$; of W_9 equals $\frac{n-2d}{l}W$.

The maximum compressive strain in diagonal b is equal to the sum of these quantities multiplied by sec θ, and equals—

$$\{n + (n - 2d)\} \frac{W}{l} \sec \theta.$$

In general, the maximum strain in any given diagonal equals—

$$\{n + (n - 2d) + (n - 4d) + (n - 6d) + \ldots + (n - 2pd)\} \frac{W}{l} \sec \theta.$$

$$\text{Max. strain} = (n - pd) \,.\, (p + 1) \frac{W}{l} \sec \theta. \qquad \text{(VI.)}$$

In diagonal a, for example, we have—

$$\begin{aligned} n &= 9 \\ d &= 2 \\ p &= 2 \\ l &= 12. \end{aligned}$$

Hence

$$\text{Max. strain} = (9 - 2 \times 2) \,.\, (2 + 1) \frac{W}{l} \sec \theta = 15 \frac{W}{l} \sec \theta.$$

This diagonal is never subject to tension from a passing load on the top flange, since there is no upper apex belonging to its system in the left segment.

When the load is uniform, the strains in the bracing may be calculated by equation III., observing that the coefficient n will, in a lattice girder, represent the number of those weights which occur between any given diagonal and the centre of the girder, and which rest only on the apices belonging to its system of triangulation. When a lattice girder contains three or more systems of triangles, a slight ambiguity occurs respecting the strains, if the load be disposed on both sides of the centre. Take, for example, W_3 and W_9, which belong to different systems, but rest on apices equally distant from the centre. The whole of W_3 may be conveyed to the left abutment through diagonals a and e, and the whole of W_9 to the right abutment, through diagonals c and d, without producing strains in the other diagonal of either system, which, indeed, might be suppressed as far as these weights are concerned. But, again, $\frac{3}{12}$ths of W_3 may be transmitted to the right abutment, and $\frac{9}{12}$ths to the

left, through the diagonals of its own system, and similarly with respect to W_9. Hence there arises a slight ambiguity respecting the strains, as they may go in either way, or partly in one, partly in the other. If, however, the girder be strong enough to sustain the strain, in whichever way it is conveyed, the safety of the structure is secured, and practically a very slight difference in the resulting strains ensues whichever method of calculation is adopted.

MONDAY, JUNE 27, 1859.

JAMES HENTHORN TODD, D. D., President, in the Chair.

J. R. KINAHAN, M.D., read an account of the discovery of certain wooden implements, found in connexion with the bones of *Megaceros Hibernicus*, in a marl-pit in the county of Clare.

J. B. Jukes, M. R. I. A., called attention to the recent observations made by Mr. Prestwich and others, in England and France, the tendency of which is to establish the coexistence of the human race with some of the races of animals now extinct, such as mammoths and bears.

The PRESIDENT read a paper—

ON THE GROUNDS FOR SUPPOSING THAT THE NAME OF THE TRIBE OF ISSACHAR OCCURS IN EGYPTIAN INSCRIPTIONS. BY THE REV. EDWARD HINCKS, D.D.

THE alleged occurrence of the name of Issachar, as of a people in Palestine, in the inscriptions of Rameses III., has been used as an argument against the opinion so generally entertained by recent Egyptologists, that the Exodus did not take place till near the end of the nineteenth dynasty. In the present paper I propose to consider, without reference to the chronological question, whether this reading of the name be admissible. As respects the latter part of the name, I cannot suppose that any objection can be made. It concludes with a double, or sometimes a single K and R. Before these we have an *unfledged bird;* and the question to be considered is, whether this can represent *Iss*, or any sound which can have passed into *Iss;* for though this be the modern pronunciation, grounded on the Masoretic points, it may not have been the ancient pronunciation.

I will endeavour to prove the two following propositions:—1st. In certain cases, of which this is one, it is admissible to supply a vowel before the consonantal character which begins a word. 2nd. The value of the *unfledged bird* was the double consonant ST. If these propositions be established, nothing more will be required to justify the reading Istakkar, or Istakar, from which Issakar naturally flows. As to the first of these propositions, I must begin with stating that since the publication of my paper "On the Number, Names, and Powers of the Letters of the Hieroglyphic Alphabet," I have been led to alter my views very considerably. So far, however, from returning to the old views, from which I there expressed my dissent, I have gone much further from them. I am now satisfied that the Greek transcriptions of the Ptolemaic age and the Coptic equivalents of hieroglyphic words are still less to be depended on than I then supposed, and that the Egyptian